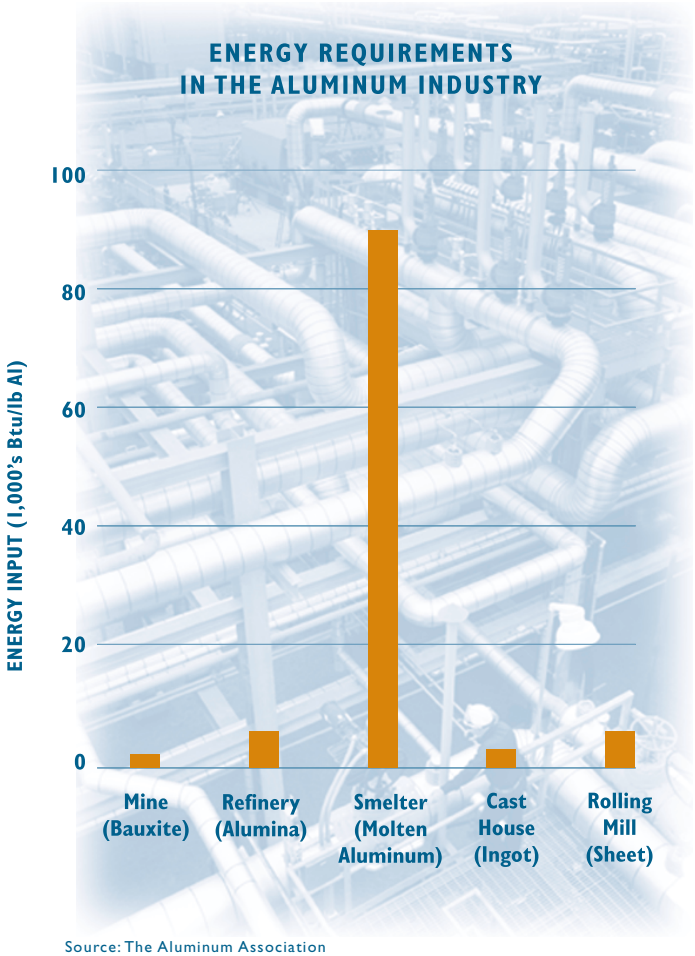
The U.S. aluminum industry is the largest in the world, annually producing more than 22 billion pounds of metal worth over $30 billion. Aluminum's light weight, resistance to corrosion, high strength, and recyclability have made it an essential material for modern economies.

PROFILE

Aluminum Industry



Source: The Aluminum Association

Value of Shipments	$32.7 billion
Total Employment	85,300
Capital Expenditures	$1,028 million
Net Trade Balance	-$1.859 billion
Net Energy Consumption	360 trillion Btu

MARKETS

The largest aluminum markets are in the transportation, packaging, and construction industries, and applications are expanding in infrastructure, aerospace, and defense. Over the past ten years, aluminum shipments have increased by an average of about 3% per year.

EMPLOYMENT

The industry directly employs about 85,300 people with a payroll of $2.7 billion. In addition, the industry supports thousands of workers in recycling facilities and other related operations. Aluminum producers are broadly dispersed across the country, contributing to national, regional, and local economies.

PRIMARY PRODUCTION

Primary aluminum production involves the refining of alumina from bauxite ore and subsequent electrolysis of the alumina. Major upheavals in world aluminum markets following the breakup of the former Soviet Union in 1989 forced plant closings that reduced U.S. smelting capacity by nearly 25%. Although the United States no longer produces 41% of the world's primary aluminum as it did in 1960, it continues to lead world production with a share of roughly 17%.

The electrolysis (smelting) of alumina to form aluminum is accomplished using the energy-intensive Hall-Heroult process. During this process, carbon anodes are gradually consumed, accounting for significant quantities of CO_2 emissions. CO_2 is also generated during the manufacture of the carbon anodes themselves and in the production of electricity to run the smelters.

SECONDARY PRODUCTION

Secondary producers recover aluminum from both new (industrial) and old (post-consumer) aluminum scrap. Recycling or secondary production saves 95% of the energy needed to produce aluminum from bauxite ore. Recycled beverage cans continue to be a major source of scrap supply. The reclamation of aluminum scrap continues to grow in importance to the industry, driven by energy and environmental considerations. In 1998, 33% of total supply was recycled aluminum.

ENERGY

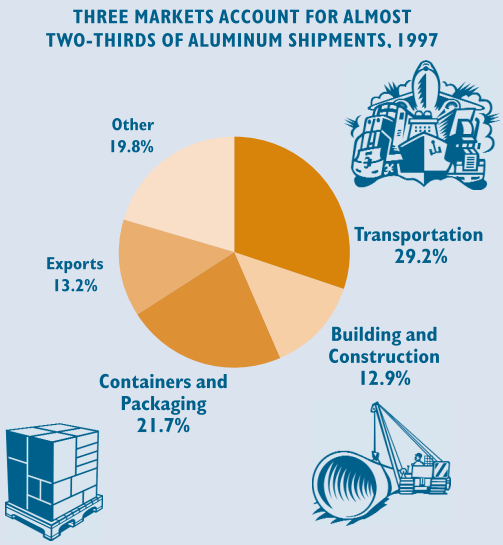
The energy-intensive smelting process accounts for the major share of energy consumption in primary aluminum production.

- Aluminum represents approximately 1.8% of all energy consumed by U.S. industry.
- In 1997, the industry spent about $2.0 billion on energy.
- Energy accounts for as much as 30% of the cost of primary aluminum production.

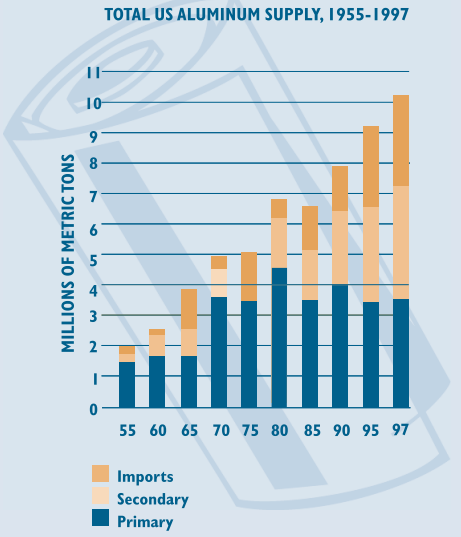
ENVIRONMENT

The biggest environmental concern associated with primary aluminum production is the generation of greenhouse gases: carbon dioxide and perfluorocarbons (mainly CF_4).

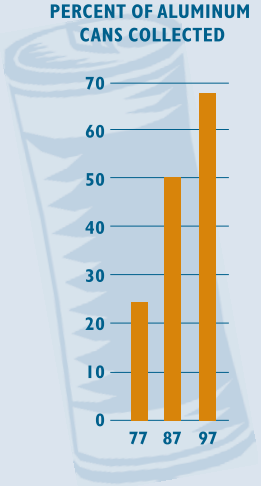
- Between 1970 and 1996, total industry emissions decreased by an estimated 27%, even though total production increased by about 59%. This decrease is attributed, in part, to an increase in secondary and a decrease in primary production.
- Combustion-related CO_2 emissions for alumina refining and smelting are estimated at 6.2 million metric tons (MMT) of carbon equivalent (ce) in 1995.
- Consumption of carbon anodes during smelting resulted in CO_2 emissions of 1.3 MMTce in 1995.
- Process emissions also included about 4.1 MMTce of perfluorocarbons in 1995.



Source: The Aluminum Association



Source: The Aluminum Association



Source: The Aluminum Association

Industry Vision and Roadmaps

ALUMINUM INDUSTRY VISION

In 1996, The Aluminum Association published *Partnerships for the Future*, the industry's vision for the year 2020. That vision established broad technical, environmental, and market goals for the industry, focusing on three sectors: raw materials, semi-fabricated products, and finished products.

ALUMINUM INDUSTRY ROADMAP

With support from DOE and the Aluminum Association, the aluminum industry developed the *Aluminum Industry Technology Roadmap*, which describes the industry's R&D strategy for accomplishing the goals outlined in the vision. The roadmap assigns highest priority to the development of improved anode and cathode technology for smelting, particularly the development of a viable inert (or non-consumable) anode. The international aluminum community has pursued the development of non-consumable anode technology for many years. The combination of this technology and wettable cathode technology could achieve the following:

- A 25% increase in the energy efficiency of electrolysis
- Up to a 10% reduction in operating costs
- A reduction in greenhouse gas emissions of up to 8 MMTce, assuming 100% market penetration

THE ALUMINUM INDUSTRY ROADMAP ESTABLISHES INDUSTRY-WIDE PRIORITIES AND PERFORMANCE TARGETS...

SAMPLE PERFORMANCE TARGETS

Primary Products	• Develop 13 kWh/kg retrofit cell (mid-term) • Develop 11 kWh/kg advanced cell (long-term) • Eliminate CO_2 emissions • Improve Bayer productivity by 20% • Develop new uses for wastes and by-products
Casting	• Increase reliability of manufacturing operations to 95% • Improve process control • Advance strip-casting technology
Rolling & Extrusion	• Use new forming technologies to reduce weight by 20% • Reduce cost of joining technologies • Increase reliability to 95% • Reduce extrusion energy use • Improve process control; improve productivity and quality
Finished Products	• Reduce metal production costs by 25% • Reduce aluminum:steel cost ratio to < 3:1 in autos • Increase aluminum use in auto markets by 40% in 5 years • Increase aluminum use in non-auto transportation markets • Increase aluminum use in infrastructure markets by 50% • Increase aluminum use in construction markets

Other key targets set by the roadmap are to improve the energy efficiency of the smelting process by 13% within 10 years (developing a cell that uses only 13 kWh/kg) and 27% by 2020 (with a cell using only 11 kWh/kg).

ADDITIONAL ROADMAPS

To better address two of the priority areas identified in the roadmap, the industry has developed two more detailed documents. These technology roadmaps focus on specific research needed for the development of inert anodes and automotive markets.

In February 1998, the U.S. aluminum industry (working with The Aluminum Association) published the *Inert Anode Roadmap*, which defines required performance characteristics to guide development of any new inert anode technology. This framework is expected to accelerate research in advanced cell technology by aligning efforts of the diverse research community toward a clearly defined goal.

The *Aluminum Industry Technology Roadmap for the Automotive Market* was developed by the industry with support from the DOE Office of Transportation Technologies (June 1999). This roadmap defines actions needed to enhance the cost-effectiveness of using aluminum in automobiles. The focus is on increasing processing efficiency and reducing the cost of converting ingot, sheet, or extrusion products into vehicle parts or components.

...AND IDENTIFIES RESEARCH TO ACHIEVE THOSE TARGETS.

RESEARCH NEEDED TO MEET PERFORMANCE TARGET IN PRIMARY ALUMINUM PRODUCTION

3-10 Years

Develop effective mathematical models
- Rate of precipitation and seeding strategy
- Control optimization
- Design optimization

Better understanding/ models of phenomena
- Electrochemical
- Gas-driven circulation
- Mass transfer
- Magnetics

Fuzzy-logic feed-forward neural net process control

Inexpensive continuous or semi-continuous sensors for super-heat, alumina, and temperature measurement

Signal analysis of cell voltage and potlines to allow intelligent control of cell

Develop retrofit cell technology for 13 kWh/kg

Optimize materials and management for control of cells
- Materials processing
- Wetted cathode
- Experimental design for materials selection
- Materials

Develop design capable of handling power modulation

Beyond 10 Years

Continued research on anode and cathode technology
- Development of non-carbon anodes

R&D on alternate reduction and refining processes

Target

Develop 11 kWh/kg advanced cell

Team & Partnership Activities

"The smarter we run our plant, the better it is for the company's bottom line, the local community, and the environment."

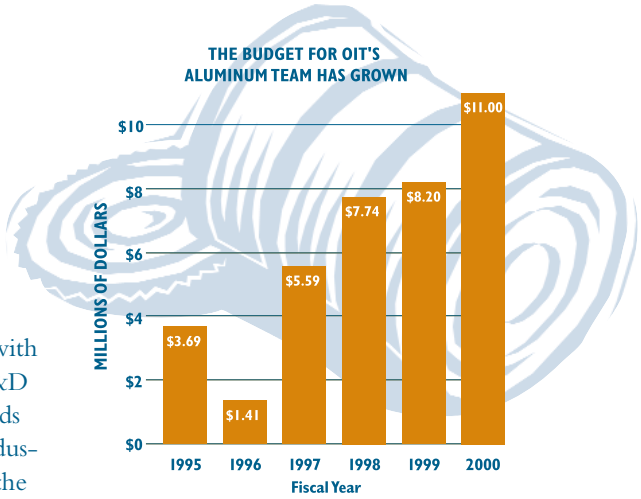
-- Cecil Pulley, Team Leader, Alcoa

ACTIVE INDUSTRY PARTICIPATION

Industry task groups work closely with OIT in crafting solicitations for R&D that will meet the most critical needs specified in the three aluminum industry roadmaps. Task groups identify the specific technology areas for the solicitations and perform technical review of the proposals that are received.

OIT's Aluminum Team makes the final selection of projects for cost-shared funding on the basis of energy-efficiency and clean production benefits. All of the projects are awarded to collaborative partnerships, many involving national labs, universities, suppliers, and equipment manufacturers, in addition to aluminum manufacturers.

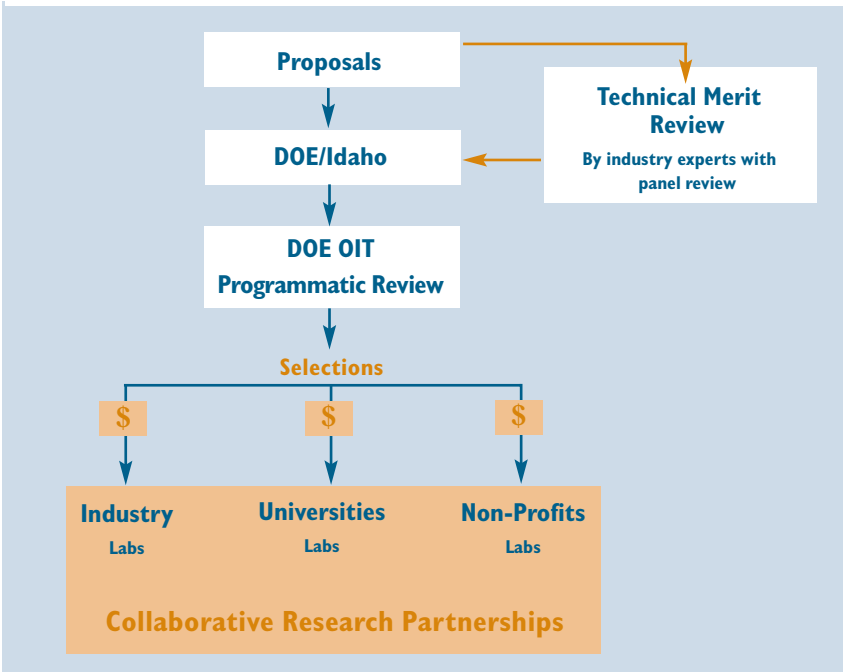
The budget provided to OIT's Aluminum Team for funding cost-shared research has grown steadily in response to the establishment of clear, industry-specified priorities for aluminum R&D. The Aluminum Association has played an active role in coordinating industry participation—both in developing the vision and roadmaps and in assisting the OIT Aluminum Team with feedback on planning and activities.



COORDINATION WITHIN OIT

OIT's Aluminum Team supplements its own R&D budget by coordinating activities with other OIT programs that can help advance aluminum industry goals. As shown in the chart on the facing page, for example, a number of innovative processes for aluminum melting and forming have been developed by small businesses with guidance and assistance from OIT's Inventions and Innovation program. Similarly, OIT's program in Continuous Fiber Ceramic Composites (CFCCs) has contributed funding to several technologies that have application in aluminum melting and forming. OIT's Steel and Metalcasting Teams also fund R&D that may have carryover benefits for aluminum production and recycling. Emerging technologies gain credibility after being demonstrated in plant conditions through OIT's NICE^3 program.

INDUSTRY PARTICIPATES IN SOLICITATIONS

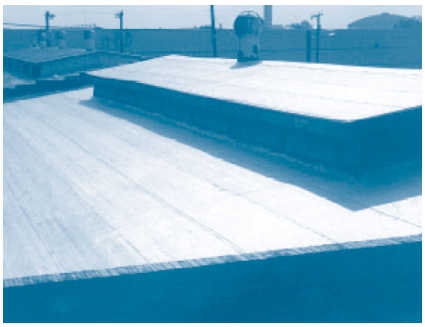


REPRESENTATIVE ALUMINUM-RELATED PROJECTS IN OIT'S PORTFOLIO

	PRIMARY PRODUCTION	SECONDARY PRODUCTION	FORMING	PRODUCTS	RECYCLING
Aluminum Industry					
•Advanced Anodes and Cathodes	●				
•Molten Salt Detection and Removal		●			
•Aluminum Melting Using O_2-Enhanced Combustion			●		
•Grain Refinement Process		●			
•Inert Metal Anode For Low-Temperature Reduction	●				
•Vertical Flotation Melter		●			
•Potlining Additives	●				
•Explosion Prevention		●			
•Recycling/Reuse of Aluminum Waste					●
•Recycling of Saltcake					●
•Semi-Solid Aluminum Alloys			●		
•Conversion of Spent Potliner to Useful Products					●
•Wettable Ceramic-Based Cathodes	●				
Inventions & Innovation					
•Reflective Aluminum Chips				●	
•Products From Metal Powders				●	
•Filtering Molten Metal	●				
Industrial Materials					
•CFCC Immersion Tubes		●			
•Heat Treating Furnace Fan			●		
•Radiant Burner Reverberatory Screen		●			
NICE³					
•Aluminum Scrap Decoater		●			
•On-Site Process for Recovering Waste Aluminum					●
BestPractices					
•Efficient Electric Motor Systems at Alcoa (Alumax)	●	●	●		
Other IOF Metal-Related Projects					
•Dilute Oxygen Combustion		●			
•Laser-Based Ultrasonic Systems			●		
•Die Life Extension			●		

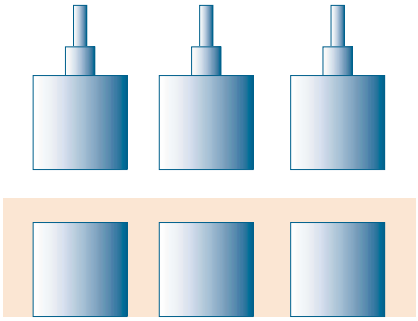
See "Selected Aluminum Portfolio Highlights" on the next two pages for additional information

Selected Aluminum Portfolio Highlights



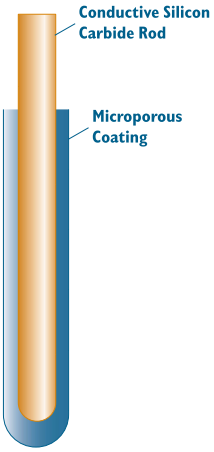
Lightweight aluminum chips form a reflective surface on asphalt roofs, reducing the need for air cooling.

The aluminum recycling industry landfills about 2 billion pounds of black dross and saltcake each year.

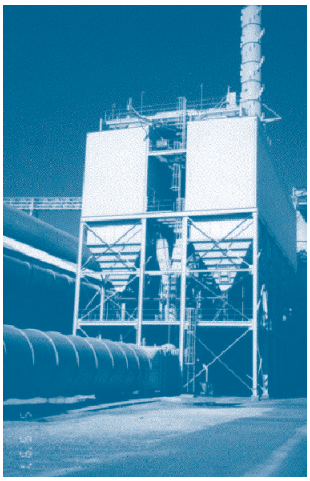


Stable ceramic cathode lining reduces energy consumed during aluminum production.

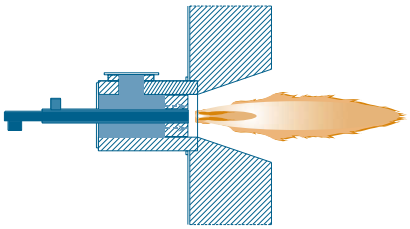
AREA	PRODUCTS	RECYCLING	PRIMARY PRODUCTION
PROJECT	**Reflective Aluminum Chips**	**Recycling of Aluminum Dross/Saltcake**	**Wettable, Ceramic-Based Drained Cathode**
DESCRIPTION	With the help of a grant funded by OIT's Inventions and Innovation Program, Transmet Corporation developed a proprietary process for producing these 1-mm-square chips that have been used on more than 33 million square feet of roofing. The chips are an inexpensive way to reduce the energy demands and pollution associated with air conditioning. • For each 10,000-square-foot warehouse roof, the chips save the equivalent of nearly 14 barrels of oil each year • Reduce air conditioning energy use (by 8.6 trillion Btu annually if *all* dwellings had such roofs) • Increase roof service life, reducing maintenance and reroofing costs • Cut installation costs and effort due to lighter weight	Conventional dross processors recover only the largest pieces of aluminum. Over 90% of the dross—which contains aluminum, salt, and the non-metallic portion (NMP)—is then landfilled. Under a NICE^3 grant, ALUMITECH and the Ohio Department of Development constructed a commercial facility that makes the NMP suitable for processing into end-use products used in steel making. Success prompted ALUMITECH to fund construction of a new facility with four times the capacity. If 80% of current aluminum/black dross is processed: • Save (potentially) over 19 trillion Btu annually • Divert 1.6 billion pounds of waste saltcake from landfills • Reduce CO_2 emissions by 50%	Ceramic-based wettable cathode materials and the necessary engineering packages are being developed to retrofit existing reduction cells as a means to improve the performance of Hall-Heroult cells. Researchers have developed the materials and will commence pilot- and industrial-scale tests of the technology. • Potential energy savings of 1,500 megawatts per year (applied to current U.S. annual production of aluminum) • Cell efficiency increase of 13 to 20%
PARTNERS	Transmet Corporation	ALUMITECH, Inc. Ohio Department of Development	Advanced Refractory Technologies Kaiser Aluminum and Chemical Corporation Reynolds Metals Company



A simple electrical probe can sense the presence of salts in molten aluminum.



Efficiency of dust collection system fans increased by 10%.



The Air-Oxygen Fuel Burner provides high-efficiency operation, low natural gas consumption, and great flexibility in operation.

FORMING

Molten Salt Detection and Removal

Chloride salts initiate defects when they agglomerate and migrate to the surface of an ingot or casting. Selee Corporation has invented a simple electrical probe that detects salts in molten aluminum and a filter that selectively removes liquid salts from the liquid metal. The project seeks to calibrate the probe and test the filter under real casting conditions to assess capacity and efficiency.

- Potential to save 0.04 trillion Btu annually
- Improve metal quality and productivity
- Reduce chlorine use and release by about 71,000 cubic ft./year

Alcoa
Selee Corporation

PRODUCTION & FORMING

Efficient Electric Motors

As part of a DOE Showcase Demonstration project, Alcoa and Jacobs-Sirrine Engineers performed an in-depth analysis of fan systems at Alcoa's Mt. Holly Aluminum Production Facility. Turning off one of four fans and changing variable inlet vane set points reduced energy demand by 382 kW annually.

- Reduced annual energy use by 12%
- Saved $103,736 per year in energy costs
- No capital cost; immediate payback
- Increased fan control accuracy
- Reduced noise and maintenance

Alcoa
Jacobs-Sirrine Engineers

SECONDARY PRODUCTION

Oxygen-Enhanced Combustion for Efficient, Low-NOx Aluminum Melting

A novel, high-efficiency, high-capacity, low-NOx combustion system is being developed and integrated with a low-cost, on-site VSA (vacuum-swing-absorption) oxygen generation system. The resulting system will improve heat transfer to the melt and help meet environmental regulations in California. The system can be installed as a retrofit to the reverberatory furnaces commonly used in melting recycled aluminum.

- Increase production rate by 30% while reducing cost
- Maintain NOx emissions at level below California standards
- Reduce emissions of CO_2 and volatile organic compounds
- Decrease energy consumption by 40% relative to baseline air-fuel operation

Air Products and Chemicals, Inc.
Brigham Young University
Wabash Alloys, L.L.C.
Argonne National Laboratory

For more information on OIT's Aluminum Portfolio, visit www.oit.doe.gov/aluminum